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Sensitivity of Site Specific Forecast Model Performance to Vertical Resolution, Model Timestep and Forcing Data

By P.M. Sheffield & W.P. Hopwood

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P. M. Sheffield & W. P. Hopwood

Abstract

The Site Specific Forecast Model (SSFM) is a 1-D version of the Unified Model, which provides the capability to produce site specific forecasts, taking into account localised effects. The SSFM is driven by 3-D output from operational NWP models and has increased vertical resolution in the boundary layer, in addition to other modifications, which increase the skill and accuracy of the forecast. The aim of this work is to investigate the sensitivity of the SSFM to vertical resolution and the timestep used within the model itself. Operationally the SSFM is driven by output from a UK Mesoscale model however NWP output is available from global NWP, giving the SSFM a global capability. Different configurations of the SSFM were created, by varying the number of vertical levels and adjusting the timestep resolution within the model, and the performance of the configurations using different forcing data was investigated. The primary aim is to find an optimum configuration which provides a high quality forecast at low computational costs.

Firstly the results from forcing the SSFM with Mesoscale data are encouraging and re-emphasise the results obtained in the 1997/98 trial by Clark *et al.* (1997). In terms of screen temperature it was found that using lower vertical resolution than the standard operational SSFM (77 levels) reduces the cold bias and minimises the RMS errors. However the inclusion of the Edwards-Slingo radiation scheme will also produce a warming effect (Pearman, 2000) that results in a warm bias in the 30 and 38 level models. Therefore based upon screen temperature alone the 51 level configuration is the optimum number of model levels. In terms of the other variables investigated, there is objectively not much to choose between the 51 and 38 level configurations, except subjectively in the forecast of fog and low cloud where extra model resolution is an advantage. This general behaviour is reproduced when the SSFM is forced with Prelim model data although the objective statistics are worse because the Prelim forcing data is effectively smoothed compared to the Mesoscale forcing data. This finding is in line with operational NWP objective verification statistics for the UK area. The impacts of increasing both the physics and radiation timesteps were investigated. Objective verification showed that over the 2 month trial period the long timestep 51 level configuration still verified better than the current SSFM operational version, although was slightly worse than the 51 level configuration with a shorter timestep.

Overall the standard operational 77 level SSFM configuration takes approximately 1 minute per site to simulate a 36 hour forecast. By decreasing the vertical resolution to 51 levels, and increasing the radiation timestep to 30 minutes and the physics timestep to 5 minutes, the runtime per site can be reduced by a factor of 6. This is a substantial saving in computational effort and vastly increases the capability for the number of sites for which SSFM forecasts can be provided for the same computational resource. Improvements to the mechanism for extracting SSFM forcing data from the Prelim model output could vastly improve the accuracy of forecasts produced for global locations from a Prelim forced SSFM run.

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1. Introduction

The Site Specific Forecast Model (SSFM) is a 1D column model designed to add site-specific forecast skill to NWP products. The SSFM is based upon the Met Office Unified Model "physics" routines, subject to some modification, and is operationally driven by output from the operational UK Mesoscale model. However the model was designed to be driven by output from any operational NWP products, not exclusively the Mesoscale model, and this work investigates the performance of the SSFM when driven from other lower resolution NWP output. The use of the large-scale dynamic forcing terms generated by global models allows the SSFM to have a truly international capability.

One of the primary reasons for the development of the SSFM was to have a higher vertical resolution in the boundary layer to represent the boundary layer structure more accurately and incorporate localised effects into the forecast. For operational purposes the SSFM is currently a 77 level model, with 53 levels in the boundary layer, representing a four-fold increase in vertical resolution within the boundary layer in comparison with the Mesoscale model. This work investigates the quality of the forecast when the vertical resolution is decreased and the effects of using longer timesteps within the model. The sensitivity of the model to all these factors is investigated along with the effect of using forcing data from a model with lower resolution but of a global nature.

The aim is to find an optimum configuration of the SSFM which provides high accuracy, high quality forecasts whilst minimising the run-time and placing a minimal strain of computing resources.

2. NWP Models

2.1. The Met. Office Unified Model

The Unified Model (UM) is a 3D grid point model solving hydrostatic dynamics on a horizontal latitude/longitude grid, and coupling together the atmosphere and the oceans. The UM uses a hybrid vertical co-ordinate system, terrain following σ levels in the lower atmosphere and pure pressure levels higher up. Operationally the Met Office runs a global model with 30 vertical levels and a horizontal resolution of 45km. A Preliminary or "Prelim" version of the model runs every 6 hours with an early data cut-off so that it can run as quickly as possible after the analysis time to give a short-range forecast for aviation. The same model is then run later out to five days when all the observations have been received This run is known as the global. The key differences between the global and the Prelim are the amount of observational data included and the length of the forecast. Boundary conditions for the North Atlantic region are output from the Prelim and used to force a higher resolution limited area model centred on the UK, the UK Mesoscale model. This has a horizontal resolution of approximately 12.5km and a vertical resolution of 38 levels and provides the forcing data for the operational SSFM over the UK.

2.2. The Site Specific Forecast Model

The Site Specific Forecast Model is a 1D single column version of the UM, comprising all the "physics" routines that are used to represent diabatic processes in the full UM: boundary layer mixing, surface exchange, longwave and shortwave radiation, cloud diagnosis, large scale precipitation and convection. As the purpose of the SSFM is to add site specific detail to the forecast the operational SSFM has an increased vertical resolution, 53 levels in the boundary layer and 77 levels in total and has several changes to improve the simulation of near-surface processes. The surface exchange scheme (MOSES) uses the Penman–Monteith approach, with soil moisture and soil temperature on multiple levels. The model also includes an interactive vegetation canopy and an urban canopy. Each grid box is "tiled" to allow for the different surface characteristics of different landuse types, and surface fluxes are calculated for each tile then aggregated over the whole grid box (Best *et al.*, 1997). A

directionally dependent down wind fetch is used – tile fractions are derived as a function of wind direction and stability using a Gaussian source area model (SAM) described by Hopwood (1998).

The boundary layer scheme models fluxes between layers in terms of mixing lengths, the vertical gradient of wind velocity and the local stability in terms of the local bulk Richardson number.

The SSFM must be externally forced with a horizontal pressure gradient and advection terms to represent the effect of larger-scale dynamics. This forcing data is extracted from 3-D NWP output, operationally from the Mesoscale model. The SSFM is running for a single column of the atmosphere above a site of interest, but in practice this site may not have the same surface altitude as that of the forcing NWP model, so an orographic correction is applied to the forcing data, essentially estimating the part of the forcing data which forms connected flow with the model fetch.

3. Description of the Trial

3.3. Trial Sites

The period used in this trial is January and February 1999. 14 prime trial sites were chosen for investigation, and are detailed in Table 1. These sites are the same as the sites used in the 1997-1998 SSFM trial, with the exception of the exclusion of S03776 (Gatwick Airport), where no observations were available.

Table 1 – Trial Sites

Site ID	Latitude	Longitude	Site	Station Height (Relative to Mesoscale Orography)	Station Height (Relative to Prelim Orography)
S03140	55.872	-4.416	Glasgow Airport	2.6	132.4
S03334	53.354	-2.275	Manchester Airport	71.8	-1.8
S03377	53.166	-0.524	Waddington	69.3	45.4
S03379	53.030	-0.483	Cranwell	53.7	45.4
S03391	53.093	-0.166	Coningsby	6.0	-17.1
S03462	52.612	-0.476	Wittering	76.2	58.5
S03502	52.112	-4.556	Aberporth	126.9	55.3
S03534	52.45	-1.733	Birmingham Airport	100.1	62.1
S03544	52.367	-1.333	Church Lawford	110.9	27.3
S03672	51.553	-0.418	Northolt	34.6	25.1
S03761	51.234	-0.943	Odiham	125.2	127.1
S03763	51.383	-0.783	Beaufort Park	83.2	74.9
S03372	51.483	-0.450	Heathrow	27.0	20.4

Table 2 – Trial Configurations

Configuration	Levels	BL Levels	Forcing	Timestep	Radiation timestep
77_mes	77	53	Mesoscale	30 s	10 min
77_pre	77	53	Prelim	30 s	10 min
51_mes	51	27	Mesoscale	60 s	10 min
51_pre	51	27	Prelim	60 s	10 min
38_mes	38	14	Mesoscale	2 min	10 min
38_pre	38	14	Prelim	2 min	10 min
30_mes	30	6	Mesoscale	5 min	10 min
30_pre	30	6	Prelim	5 min	10 min
51_long	51	27	Mesoscale	5 min	30 min

3.4. Model Configuration

The standard operational SSFM configuration, as previously documented by Clark *et al.* (1997) and Best *et al.* (1997) is:

- 77 vertical levels, 53 levels in the boundary layer
- 30 second physics timestep, 10 minute radiation timestep
- tile treatment of surface exchange from inhomogeneous surfaces, including an urban canopy
- directionally dependent fetch - tile fractions are derived as a function of wind direction and stability using a source area model (SAM)
- orographic correction of forcing data

This is equivalent to a four-fold increase in the vertical resolution of the Mesoscale model within the boundary layer (BL). Operationally the SSFM uses Mesoscale forcing data, 100m resolution orography and 25m Institute of Terrestrial Ecology (ITE) landuse data, divided into 7 land-use classes.

3.5. Vertical Resolution

In order to investigate the sensitivity to vertical resolution degradation four standard vertical resolutions were chosen for this trial

- 77 levels, 53 in BL – as in the standard SSFM
- 51 levels, 27 in BL– double the Mesoscale resolution in the BL
- 38 levels, 14 in BL – as in the operational Mesoscale model
- 30 levels, 6 in BL – as in the operational global model

Default physics and radiation timesteps were chosen for each vertical resolution and these were kept constant throughout the initial trial. It should be noted that the radiation timestep is computationally the most expensive part of the code and initially this was kept the same for each configuration to look purely at the effects of reducing the vertical resolution. Full details of each configuration are given in Table 2.

3.6. Forcing Data

The four resolutions listed above were run twice for the 2 month trial period, once using forcing data from the Mesoscale model and then again using forcing data taken from the Prelim model. The Mesoscale forced runs were started at 00Z, 06Z, 12Z, 18Z and run for 36

hours. The forcing data for 01/01/1999 18Z was incomplete so the Mesoscale trials were started from 00Z on the 2nd January. More significant problems were encountered with the Prelim forcing data. Cloud liquid water (qcl) and cloud frozen water (qcf) fields were only available for 00Z, 03Z and 12Z and no times in between. This caused the model to fail and the only solution was to re-extract the forcing data as a combination of the available Prelim data and global model data. Since the global model is only run twice daily this meant that forcing files were only available for the 00Z and 12Z runs. As a consequence of this the trial results have only been verified for the 00Z and 12Z runs. This problem arose because these two moisture fields were not routinely archived prior to April 1999 and future use of Prelim forcing data by the SSFM should not be an issue. In the remainder of this report Prelim forcing is referring to the combination of Prelim and global model forcing. In addition to this, on several occasions Prelim forcing data was missing. The SSFM can cope with this and continue but no model output is generated for these missing runs.

3.7. Orography and Land Use

For the Mesoscale forced runs the 100m Mesoscale orography and the 25m ITE landuse were used. In order to assess the SSFM capability for locations outside to Mesoscale area, where the DTED 100m orography and ITE 25m landuse are not available, the 1km "GLOBE" (Global Land One km Base Elevation) orography and IGBP (International Geosphere-Biosphere Programme) landuse are used with Prelim model forcing data.

3.8. Maximum Possible Timestep

By increasing the length of the physics and more critically the radiation timestep used within the model the overall simulation time can be significantly reduced. However this is only a reasonable thing to do if the inherent numerical stability of the model, as measured by the Courant condition, is not compromised. The Courant condition itself is a function of timestep, grid resolution and model state but essentially translates into saying the model solution will be unstable, and likely to cause large simulation errors and even model failures, when the simulated mixing/advection over a timestep is greater than the resolution of model (vertical) grid. The maximum length of timestep possible for each of the four vertical resolutions was investigated for the site S03672, (Northolt) for a convective case (12/11/1997 00Z), i.e. a case where the model vertical mixing is likely to be large, before the accuracy of the forecast deteriorated significantly. This was done subjectively and provided a rough estimate of the increase in timestep that could be pragmatically achieved. Figure 1 illustrates that if the physics/radiation timesteps are increased to 5 mins/30 mins the timing of the convective rainfall is the practically the same as at 2mins/10mins although the rainfall rate is overestimated. However if the timesteps are increased to 5mins/1hour the accuracy in convective rainfall prediction deteriorates significantly, with the first rain overestimated and the second incidence was not forecast at all. Therefore it was subjectively decided that the timesteps could not be increased beyond 5 mins/30 mins without a significant loss in forecast accuracy.

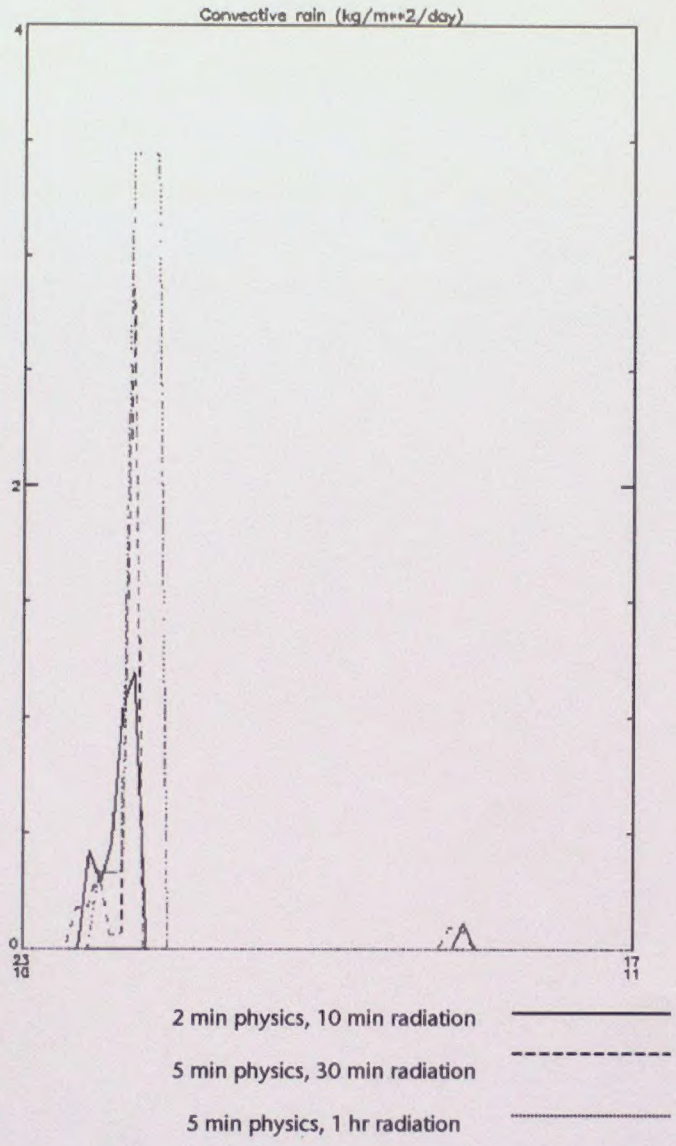


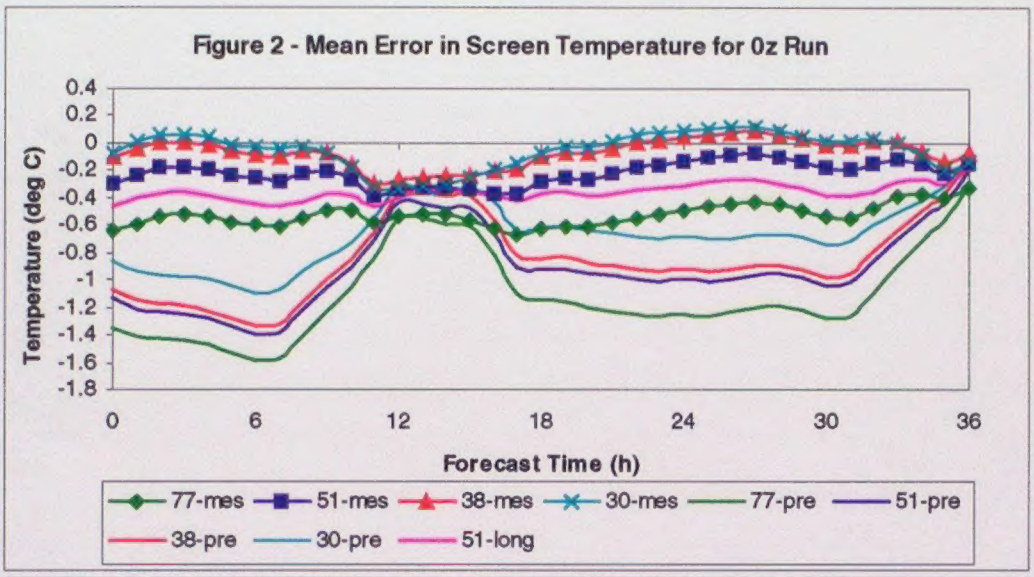
Figure 1 – Convective Rainfall with varying timesteps Northolt – 12/11/1997

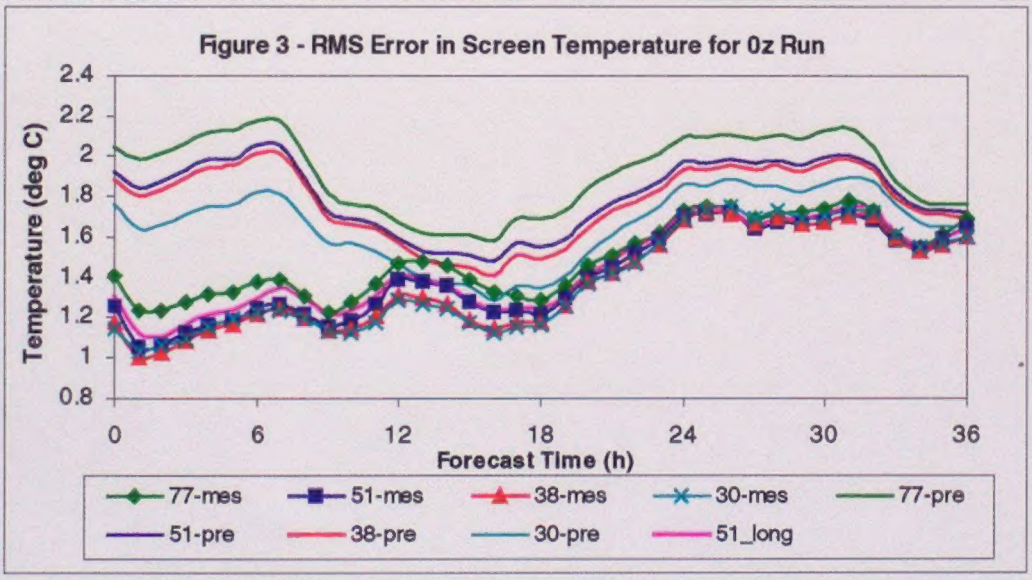
After initial verification, anticpating later results, over the two month trial period the optimum vertical resolution, in terms of simulation accuracy and simulation time, was selected. This configuration was then used to simulate the trial period at the longest timestep indicated by the convective case study. This "long timestep" configuration (*51_long*) driven from Mesoscale forcing called the radiation scheme every 30 minutes as opposed to every 10 minutes and the other physics schemes every 5 minutes.

4. Objective Verification

4.1. Screen Level Temperature

The 00Z and 12Z plots of the bias and RMS errors in screen temperature, averaged over all





trial sites, show similar overall behaviour so only the 00Z plots are shown in Figures 2 & 3.

From these figures it is immediately obvious that the simulations performed from Prelim data are significantly worse when compared to the Mesoscale. All the runs forced from Prelim data have a larger cold bias and RMS error, in particular there seems to be a large cold bias in the nighttime Prelim forcing. The Mesoscale forced runs also tend to have a cold bias, however while these show less diurnal variation they do increase during the daytime, as opposed to night-time. This result is consistent with the monthly operational NWP verification scores. In terms of the bias there appears to be a dependence of performance on the vertical resolution for simulation forced by both Prelim and Mesoscale data. This is also true for the RMS errors in the Prelim forced simulations but not for Mesoscale forced simulations. This is because reducing the vertical resolution is effectively tuning the orographic correction scheme to the vertical scales of orographic perturbations resolved within the driving model orography such that the diagnosis of fully blocked orographic flow

becomes more difficult with decreasing vertical resolution. In essence a thick vertical layer is harder to block than a thin one, hence the diagnosed fully blocked layer will be a lower model level and hence warmer, assuming an adiabatic temperature profile.

An overall view of the performance can be seen from the verification of maximum and minimum hourly screen temperatures. The results are shown in Tables 3 and 4. Daytime maximum temperatures have been taken from the 00Z run and nighttime minima from the 12Z. Forecast maxima are colder than observed, the only exception being Aberporth for the Mesoscale forced simulations. The largest cold biases occur at Glasgow, Manchester and Heathrow. The Prelim maxima are significantly colder, again worst at Glasgow, Manchester and Heathrow, all improving with decreasing vertical resolution.

Minimum temperatures from Mesoscale simulations again tend to be slightly cold, with the exception of Cranwell, Coningsby, and Wittering that are slightly warm. In general all the minimum temperature biases are several tenths of a degree cooler than in the 1997/98 trial (Clark *et al.*, 1998), although Beaufort Park and Heathrow are significantly colder. This is probably due to changes in the physical parmetrizations both within the SSFM and the driving model, most notably the inclusion of the mixed phase microphysics scheme. Although the cool biases are greater, the RMS errors have been reduced in all cases, again the exception being Beaufort Park and Heathrow where the RMS error is of comparable magnitude to the earlier trial. Once again the Prelim runs are significantly worse with some biases in excess of –2K but the degradation in is line with the difference between the Prelim and Mesoscale NWP operational verification statistics.

4.2. Dew Point Temperature

Figures 4 & 5 show the mean and RMS errors in the dew point temperature averaged over all 13 sites from the 00Z run. A strong diurnal variation is seen with a warming during the day and cooling at night. This bias is most pronounced for the runs using Prelim forcing data, with the 77 level configuration performing the best in daytime and 30 level configuration best during the night, that is the 77 level run tends to be cooler throughout. The variation in the Mesoscale diurnal biases is not so pronounced with all 4 configurations having similar magnitudes particularly at night, although the 30 level configuration performs better during the daytime. There is negligible difference between the 4 Mesoscale runs in terms of RMS error, and for the Prelim runs the 30 level configuration verifies best. Generally the individual site plots show the Prelim runs tending to be cooler than their Mesoscale equivalents at night and warmer during the day, although at Glasgow, which is over 100m higher relative to the Prelim orography, the dewpoint temperature is persistently about 1K lower than in the Mesoscale forced simulatons.

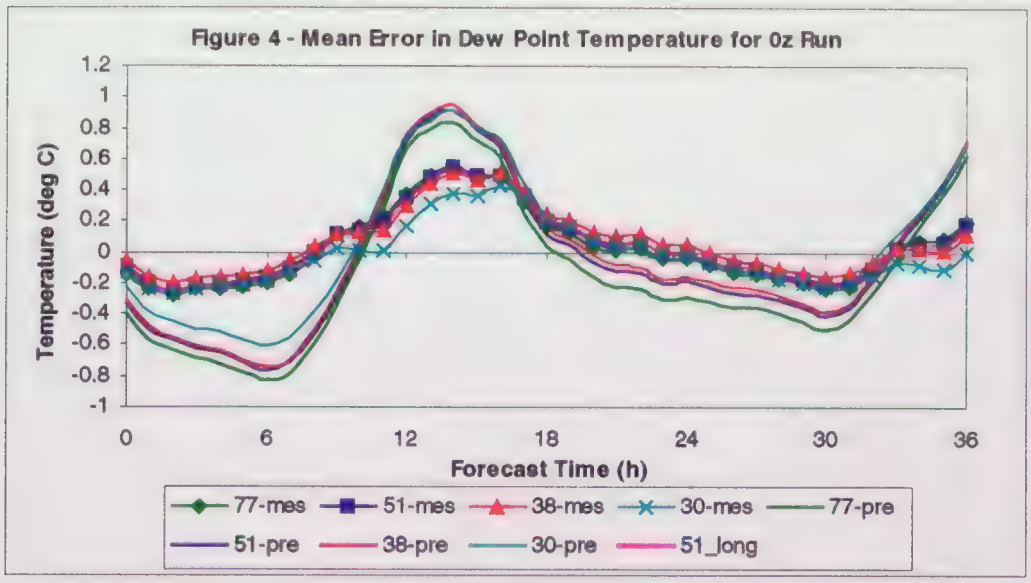


Figure 4 - Mean Error in Dew Point Temperature for 0z Run
Temperature (deg C)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
6
12
18
24
30
36
Forecast Time (h)
77-mes
51-mes
38-mes
30-mes
77-pre
51-pre
38-pre
30-pre
51_long

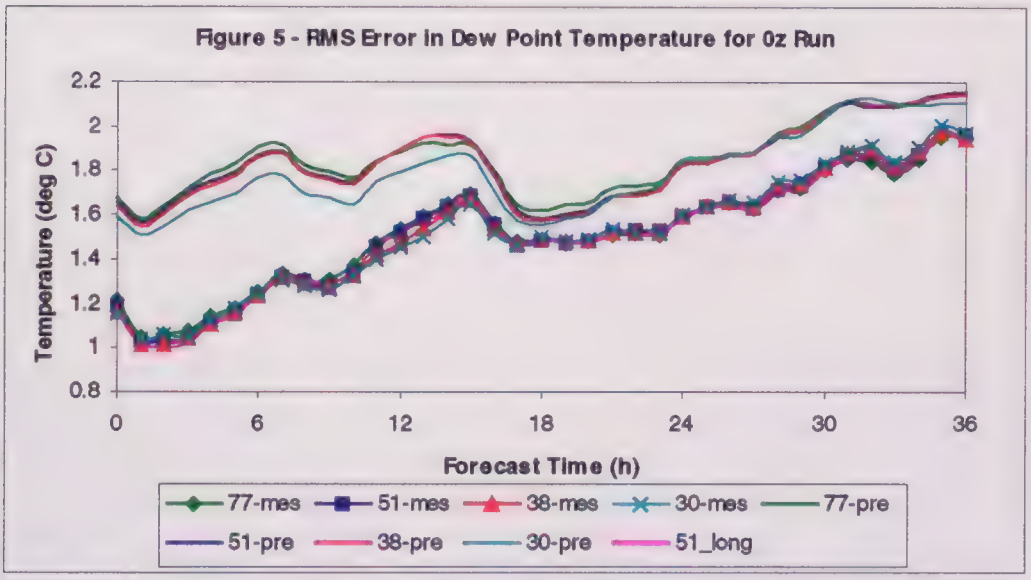


Figure 5 - RMS Error in Dew Point Temperature for 0z Run
Temperature (deg C)
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0
6
12
18
24
30
36
Forecast Time (h)
77-mes
51-mes
38-mes
30-mes
77-pre
51-pre
38-pre
30-pre
51_long

Table 3 – Daily Maximum Temperatures from 00Z run

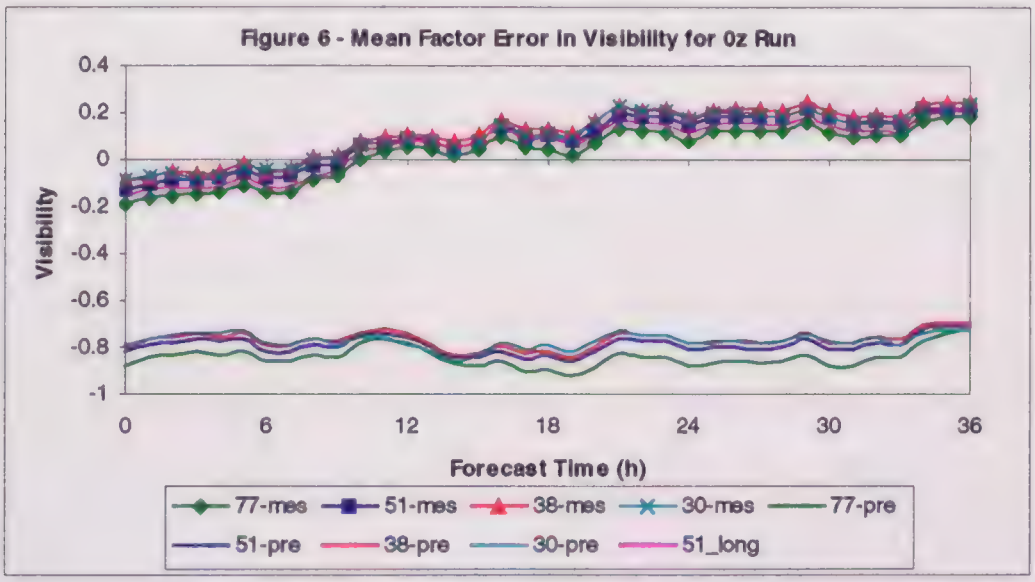
Levels	77_mes	77_mes	77_pre	77_pre	51_mes	51_mes	51_pre	51_pre	38_mes	38_mes	38_pre	38_pre	30_mes	30_mes	30_pre	30_pre
Site	*Bias*	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*
S03140	-0.980	1.371	-2.424	2.735	-0.631	1.135	-2.187	2.786	-0.522	1.029	-2.100	2.417	-0.549	1.000	-2.031	2.293
S03334	-0.890	1.533	-0.725	1.822	-0.670	1.426	-0.520	2.013	-0.593	1.365	-0.439	1.599	-0.569	1.381	-0.345	1.425
S03377	-0.378	1.266	-0.623	1.298	-0.197	1.250	-0.534	1.416	-0.136	1.227	-0.435	1.143	-0.141	1.258	-0.380	1.058
S03379	-0.368	1.377	-0.704	1.421	-0.159	1.340	-0.593	1.526	-0.09	1.323	-0.484	1.244	-0.082	1.296	-0.422	1.151
S03391	-0.383	1.414	-0.445	1.281	-0.119	1.396	-0.329	1.519	-0.023	1.341	-0.216	1.140	-0.051	1.38	-0.148	1.048
S03462	-0.407	1.378	-0.658	1.354	-0.214	1.350	-0.546	1.468	-0.091	1.28	-0.455	1.255	-0.078	1.256	-0.396	1.192
S03502	0.100	1.028	-0.235	1.296	0.244	1.053	0.340	1.088	0.275	1.068	0.427	1.312	0.21	1.066	-0.353	1.204
S03534	-0.581	1.357	-0.209	1.332	-0.322	1.266	-0.097	1.255	-0.233	1.21	-0.055	1.253	-0.236	1.185	-0.034	1.247
S03544	-0.355	1.288	-0.124	1.271	-0.163	1.254	-0.243	1.233	-0.105	1.218	-0.331	1.232	-0.073	1.254	-0.368	1.164
S03672	-0.521	1.372	-0.645	1.346	-0.316	1.240	-0.478	1.505	-0.192	1.049	-0.418	1.209	-0.251	0.982	-0.359	1.114
S03761	-0.365	1.215	-0.728	1.442	-0.211	1.143	-0.064	1.377	-0.157	1.081	-0.552	1.271	-0.173	1.031	-0.534	1.168
S03763	-0.547	1.265	-0.867	1.434	-0.346	1.154	-0.754	1.575	-0.278	1.1	-0.662	1.262	-0.304	1.073	-0.612	1.246
S03772	-0.717	1.625	-0.990	1.583	-0.435	1.380	-0.813	1.86	-0.307	1.225	-0.731	1.366	-0.38	1.184	-0.677	1.306

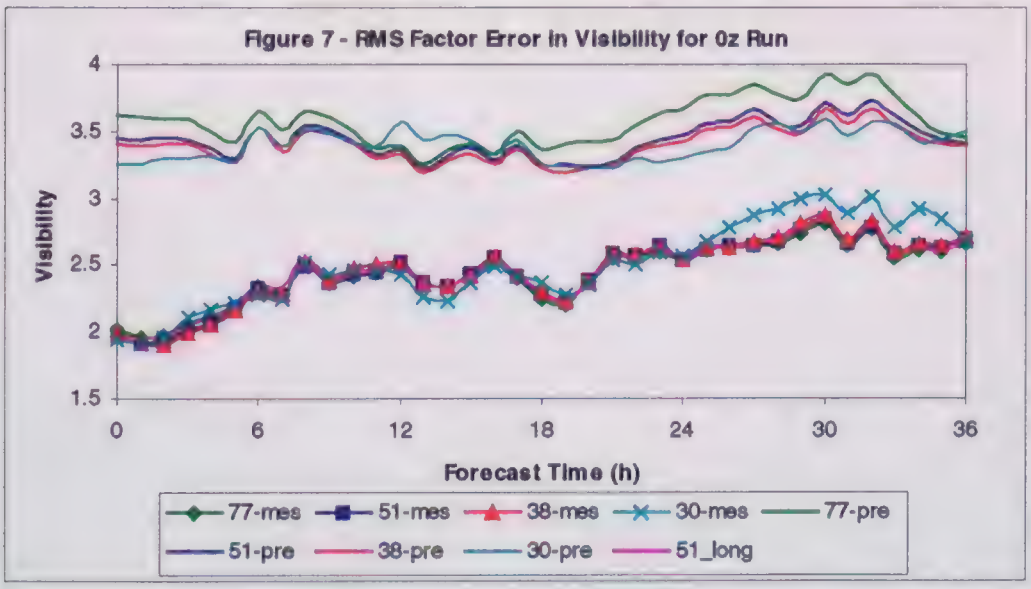
Table 4 – Daily minimum Temperatures from 12Z run

Levels	77_mes	77_mes	77_pre	77_pre	51_mes	51_mes	51_pre	51_pre	38_mes	38_mes	38_pre	38_pre	30_mes	30_mes	30_pre	30_pre
Site	*Bias*	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*
S03140	-0.132	1.719	-1.499	2.265	0.291	1.640	-1.281	2.120	0.394	1.653	-1.202	2.077	0.392	1.613	-1.023	1.951
S03334	-0.463	1.409	-1.040	1.779	-0.206	1.356	-0.764	1.681	0.001	1.279	-0.677	1.609	0.500	1.353	-0.494	1.591
S03377	-0.419	0.991	-1.213	1.670	-0.168	0.936	-1.052	1.581	-0.033	0.926	-0.991	1.570	0.730	1.024	-0.663	1.356
S03379	0.005	1.115	-0.947	1.516	0.271	1.117	-0.764	1.399	0.039	1.132	-0.685	1.365	0.497	1.195	-0.343	1.244
S03391	0.102	1.243	-0.673	1.346	0.373	1.248	-0.484	1.248	0.523	1.285	-0.416	1.229	0.514	1.321	-0.082	1.163
S03462	0.135	1.206	-1.111	1.550	0.394	1.250	-0.954	1.447	0.509	1.288	-0.851	1.398	0.591	1.332	-0.508	1.269
S03502	-0.127	1.340	-0.577	1.960	0.218	1.310	-0.378	2.001	0.353	1.416	-0.293	2.007	0.378	1.363	-0.120	1.993
S03534	-0.173	1.537	-0.266	1.374	0.167	1.422	-0.058	1.365	0.327	1.427	-0.106	1.375	0.381	1.412	-0.046	1.432
S03544	-0.194	1.007	-0.626	1.819	0.08	1.003	-0.397	1.253	0.203	1.044	-0.324	1.239	0.252	1.118	-0.042	1.219
S03672	-0.328	1.392	-1.101	2.128	-0.054	1.308	-0.822	1.718	0.169	1.299	-0.839	1.730	0.136	1.402	-0.701	1.722
S03761	-0.157	1.415	-0.979	2.112	0.094	1.380	-0.818	2.061	0.261	1.380	-0.714	2.024	0.283	1.325	-0.457	1.972
S03763	-0.619	1.543	-1.578	2.317	-0.299	1.367	-1.361	1.999	-0.145	1.353	-1.261	1.945	-0.051	1.284	-0.980	1.902
S03772	-1.028	1.679	-1.850	1.299	-0.639	1.498	-1.557	2.120	-0.455	1.413	-1.477	2.062	-0.509	1.429	-1.305	2.097

4.3. Visibility

Figures 6 & 7 show the visibility. They show the most striking difference between the use of Mesoscale and Prelim forcing. Both the 00Z and 12Z runs from the Mesoscale show biases of between –0.2 and +0.2 compared to around -1.0 for Prelim forcing. In terms of RMS errors the Mesoscale vastly outperforms the Prelim. This difference arises for a number of reasons: the lower vertical resolution in the Prelim model boundary layer will lead to an effectively smoothed moisture field when compared to the Mesoscale boundary layer; the errors in temperature and dewpoint are also reflected in the visibility; the station height will play a large part, stations which are artificially raised in the Prelim orography will be colder, have less capacity to hold moisture and hence will be prone to condensation, reducing the diagnosed visibility; most importantly the Prelim model does not contain prognostic aerosol concentration hence a default value has to be assumed making the visibility diagnosis primarily dependent upon the moisture fields. It was noticeable in all the Prelim model runs that the visibility diagnostics were predominantly less than 10km whereas using Mesoscale data the visibility was nearly always in excess of 10km, reflecting this homogeneous aerosol.

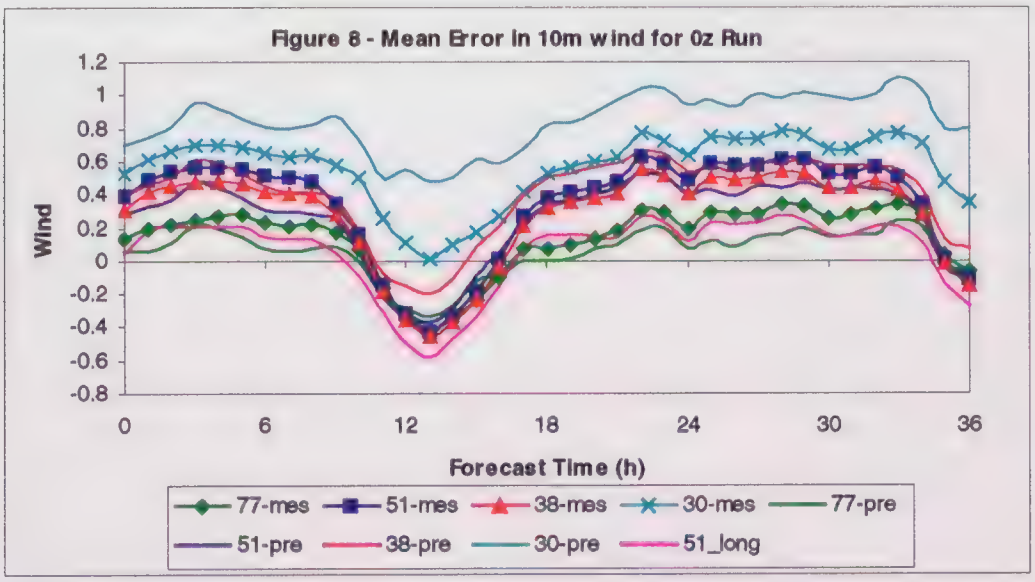


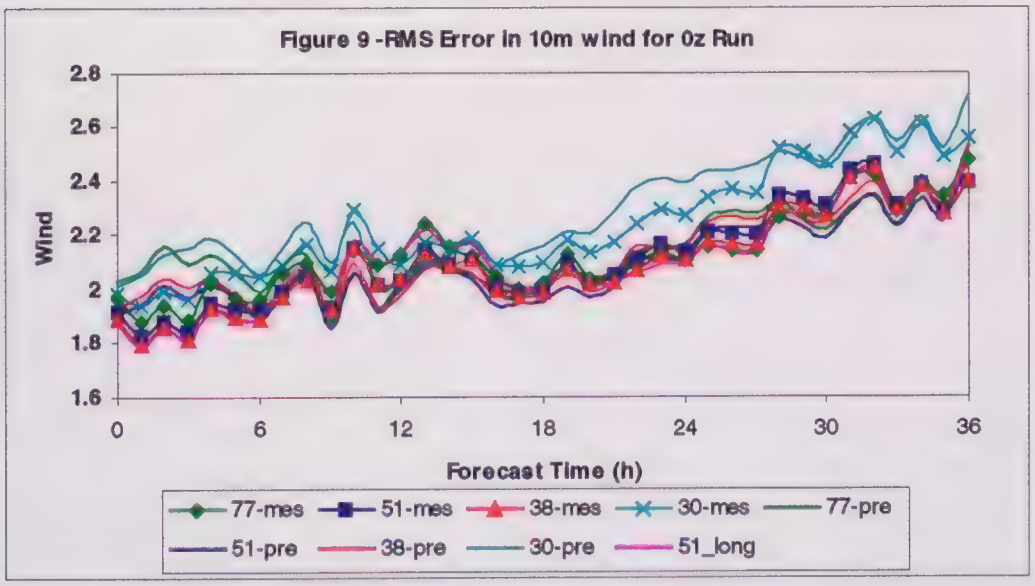


Again there is little to choose between the 77, 51 and 38 level Mesoscale runs in terms of RMS, but the 77 level does minimise the positive bias in visibility at later forecast times due to a better representation of the moisture profile.

4.4. 10m Windspeed

For the prediction of 10m windspeed 77 levels minimises the mean error, using both Prelim and Mesoscale forcing. However the RMS error is minimised by using Mesoscale forcing and either 51 or 38 model levels. In all configurations there is a tendency to underestimate the windspeed during the hours of maximum incoming short wave radiation (see Figures 8 & 9). The 30 level configurations are unacceptable in terms of RMS errors. This is because





in the 30 level model the lowest model level is actually above 10m. At higher vertical resolution, when the first model level falls below 10m the 10m windspeed is calculated by interpolating between the model levels above and below screen level. However if the first level is higher than 10m, the 10m windspeed is calculated using the ratio of bulk transfer coefficients, a function of roughness lengths and stability. This method of estimating 10m windspeed is not as accurate as using direct interpolation from model levels, hence the significantly worse performance from both types of forcing.

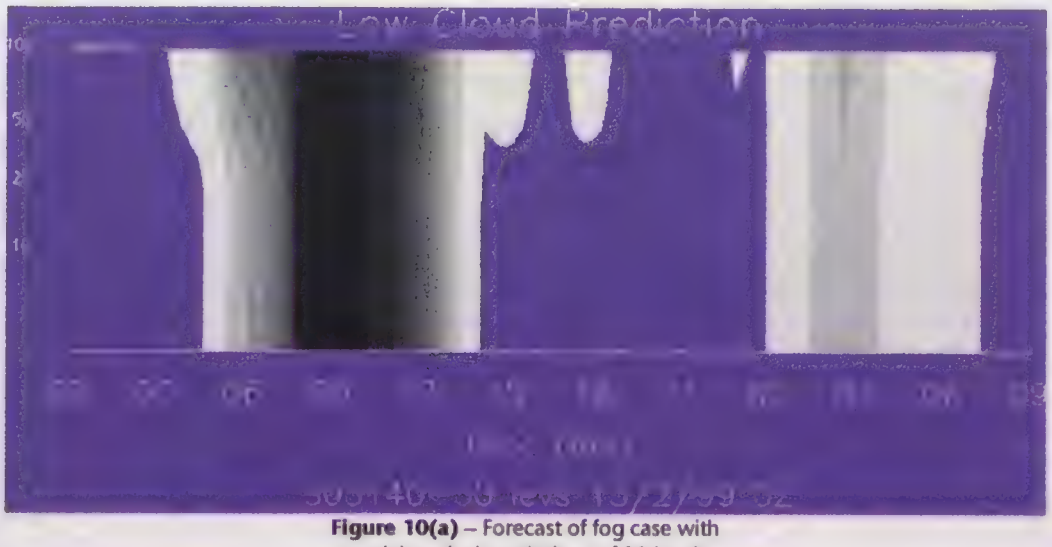


Figure 10(a) – Forecast of fog case with model vertical resolutions of 30 levels

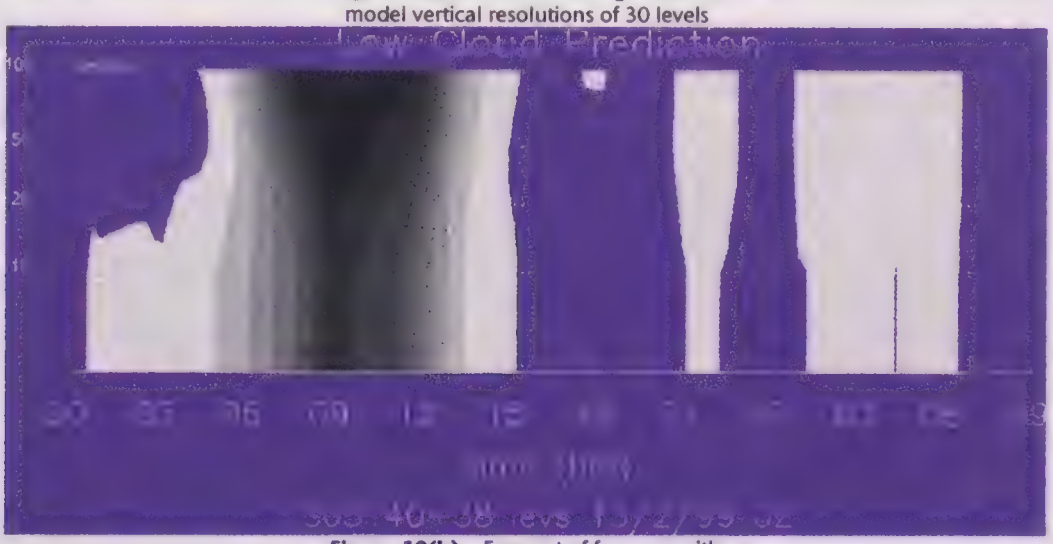


Figure 10(b) – Forecast of fog case with model vertical resolutions of 38 levels

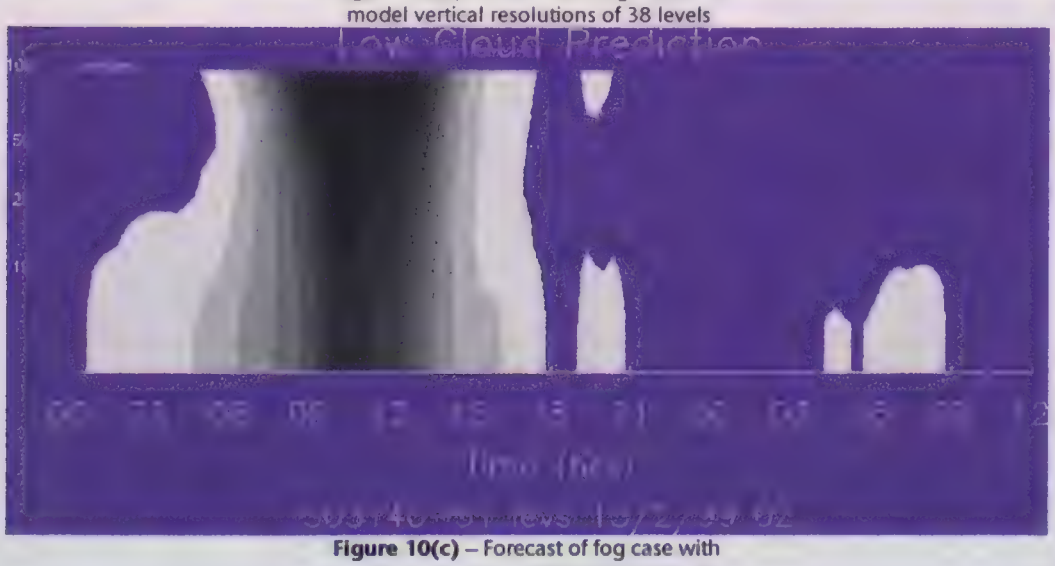


Figure 10(c) – Forecast of fog case with model vertical resolutions of 51 levels

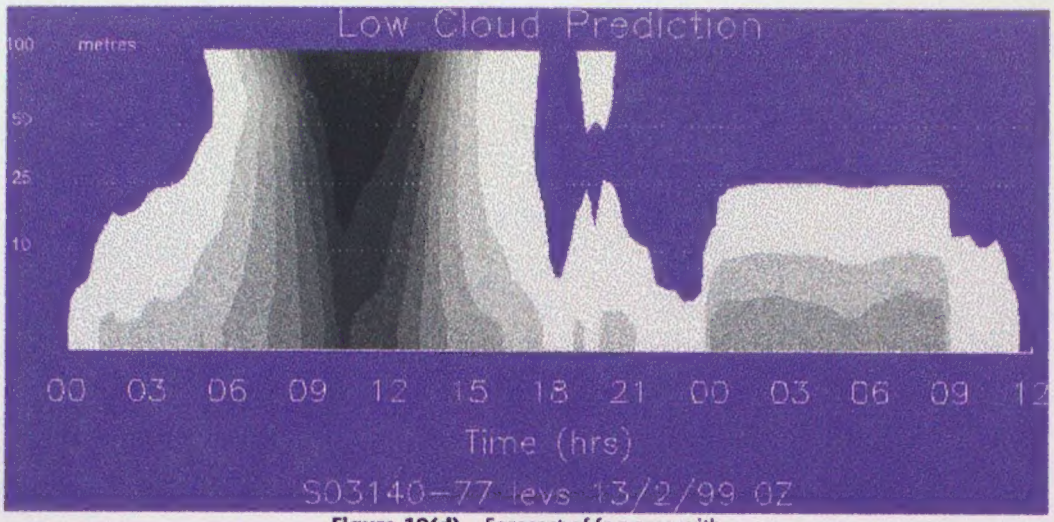


Figure 10(d) – Forecast of fog case with model vertical resolutions of 77 levels

4.5. Optimum Configuration based upon Verification

The trial was run for January and February 1999 which was before the Edwards Slingo radiation scheme was added into the Mesoscale or SSFM model. In general this scheme causes a warming of around 0.3K. This radiation scheme is now included in the operational version so any forecasts produced from real time forcing will be subject to this warming. Since the 38 and 30 level screen temperature biases become positive during the night the 51 level configuration is preferable as with the additional warming due to Edwards Slingo the bias will be minimised. In terms of dew point and visibility there is little to choose between the various configurations, however the version with 51 levels will integrate quicker than the standard 77 level SSFM but will still have an increased number of model levels in the boundary layer to add the subjective local surface forecast detail, compared to the 14 in the Mesoscale. This is desirable for the forecasting of the formation and dispersion of fog. This is illustrated in Figure 10 where the subjective performance of each model configuration is compared for a fog case during the trial period. The observed visibilities are shown in Table 5. The initial onset of the foggy conditions on 13-2-1999 occurred around 02Z. The 30 level configuration doesn't forecast fog until significantly later. The 51 and 38 level models perform slightly better, forecasting some low cloud from midnight onwards, thickening around 04-05Z. Only the 77 level model predicts the thicker cloud developing around 02Z. From the observations it can be seen that the lowest visibility conditions occur between 0900Z and 12Z. All the configurations capture this to some degree, although the timing of the 30 level model is slightly off, but only the 77 level model actually shows the variation in the low cloud cover during this period, worst at 10-11Z. The following day another period of poor visibility occurs between 04Z and 08Z. The 30 level configuration predicts reasonably thick low cloud between 02Z and 04Z which is not in line with observations. 38 and 51 levels get the timing of the low cloud more precisely but only the 77 level model has any variation in the amount of cloud forecast, but again it forecasts the onset of the low cloud too early. In general it can be seen the configurations with the highest vertical resolution close to the surface give the best subjective forecast of the fog formation and subsequent dissipation. This is because the thinner the model level thickness the quicker it will respond to increases or decreases in moisture content. A thinner model layer will reach saturation quicker whereas a thicker layer may not saturate, in one case fog would be forecast, in another the formation would be missed. Hence this is particularly important in forecasting shallow fog.

For the above reasons it was decided to re-run the trial for the 51 level Mesoscale configuration using a long timestep (*51_long*), and assess the performance of this against the standard 77 level SSFM and the 51-mes configuration. See Table 2 for configuration details.

Table 5 – Observations from 03140 for Fog Case

13-2-1999		14-2-1999	
Hour	Visibility(m)	Hour	Visibility(m)
0	25000	0	18000
1	25000	1	20000
2	400	2	22000
3	20000	3	25000
4	600	4	8000
5	400	5	6000
6	400	6	6000
7	400	7	6000
8	400	8	12000
9	300	9	25000
10	200	10	30000
11	100	11	25000
12	300	12	20000
13	400		
14	5000		
15	7000		
16	12000		
17	12000		
18	12000		
19	14000		
20	14000		
21	14000		
22	15000		
23	16000		

4.6. Long Timestep Verification (*51-long*)

The 36 hour verification plots showed the same basic profile as the other Mesoscale forced runs documented in the previous section. For each variable the average bias and RMS error over the 36 hour run was taken and the results are summarised in Table 6.

Table 6 – Verification Statistics from Long Timestep Trial

Run		Min Temp		Max Temp		Temp		Dew		Visibility		Wind	
		Bias	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*	*Bias*	*RMS*
00Z	77_mes			-0.49	1.35	-0.53	1.49	0.02	1.52	0.03	2.44	0.13	2.13
	51_mes			-0.27	1.26	-0.22	1.41	0.04	1.51	0.09	2.44	0.34	2.11
	51_long			-0.29	1.25	-0.36	1.44	0.03	1.51	0.06	2.45	0.05	2.11
12Z	77_mes	-0.26	1.35			-0.55	1.44	0.13	1.57	0.01	2.34	0.10	2.12
	51_mes	0.04	1.30			-0.26	1.36	0.15	1.56	0.07	2.35	0.29	2.10
	51_long	-0.18	1.32			-0.37	1.39	0.14	1.56	0.04	2.36	0.04	2.10

The 51 level configuration running with the longer timestep verifies objectively better than the standard 77 level SSFM configuration but slightly worse than the standard 51 level configuration for temperature, dew point and visibility. The 10m wind actually performs better at the longer timestep in terms of both bias and RMS error. From this it would seem that no significant loss of accuracy would be encountered by running on 51 levels and increasing the timestep.

5. Conclusions

The results from forcing the SSFM with Mesoscale data are encouraging and re-emphasise the results obtained in the 1997/98 trial by Clark *et al.* (1998). In terms of screen temperature it was found that using lower vertical resolution than the standard operational SSFM (77 levels) reduces the cold bias and minimises the RMS errors. However the inclusion in the Edwards-Slingo radiation scheme will also produce a warming effect (Pearman, 2000) that results in a warm bias in the 30 and 38 levels models. Therefore based upon screen temperature alone the 51 level configuration is the optimum number of model levels. In terms of the other variables investigated, there is objectively not much to choose between the 51 and 38 level configurations, except subjectively in the forecast of fog and low cloud where extra model resolution is an advantage.

The impact of increasing both the physics and radiation timesteps were investigated. Objective verification showed that over the 2 month trial period the long timestep 51 level configuration still verified better than the current SSFM operational version, although was slightly worse than the 51 level configuration with a shorter timestep. This general behaviour is reproduced when the SSFM is forced with Prelim model data although the objective statistics are worse because the Prelim forcing data is smoothed (3 hourly versus 1 hourly) compared to the Mesoscale forcing data. This finding is in line with operational NWP objective verification statistics for the UK area. The ability to force the SSFM from Prelim output gives the SSFM an international utility, particularly if the Prelim forcing could be improved so that the Prelim-based output has smaller verification errors more in line with those produced from using Mesoscale forcing.

6. Future Work

It is expected that the accuracy of SSFM forecasts for international sites would be much improved if forcing data from the Prelim model was produced at hourly intervals as opposed to being smoothed out over 3 hours. Useful work to be carried out in the future should include an investigation of modifying the Prelim model to output at hourly intervals and a further trial to assess the benefits in forecast accuracy resulting from this change.

7. References

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